tional image sensors tend to suffer from cross-talk issues and/or have degraded performance in terms of optical loss or quantum efficiency.

In contrast, embodiments of the present disclosure facilitate the formation of buried or embedded color filters. In more detail, the embodiments discussed above with reference to FIGS. **1-15** and **27** implements an etching-stop layer to allow the oxide capping layer to be removed without damaging the buffer layer (or other layer in the optical path of the image sensor) below. The embodiments discussed above with reference to FIGS. **16-26** and **28** utilizes an ONO-like structure to also allow the oxide capping layer to be removed without damaging the buffer layer (or other layer in the optical path of the image sensor) below.

In each of these two embodiments discussed above, a metal grid is formed that defines openings that are reserved for the formation of buried color filters. Stated differently, according to the embodiments of the present disclosure, the color filters can be formed to be embedded or buried in the openings defined by the metal grid, rather than being formed on a flat surface above the metal grid. Consequently, the metal grid can more effectively prevent the light from incorrectly entering an adjacent pixel (since the metal grid is at the same level as the color filters), thereby reducing cross-talk. The fact that the color filters are formed within the openings defined by the metal grid also means that the color filters are "self-aligned", thereby obviating any alignment constraints between the metal grid and the color filters. In addition, the shorter optical path between the color filters and the pixels increases light reception and enhances quantum efficiency.

One embodiment of the present disclosure pertains to a semiconductor image sensor device. The image sensor device includes a substrate having a first side and a second side that is opposite the first side. An interconnect structure is disposed over the first side of the substrate. A plurality of radiation-sensing regions is located in the substrate. The radiation-sensing regions are configured to sense radiation that enters the substrate from the second side. A buffer layer is disposed over the second side of the substrate. A plurality of elements is disposed over the buffer layer. The elements and the buffer layer have different material compositions. A plurality of light-blocking structures is disposed over the plurality of elements, respectively. The radiation-sensing regions are respectively aligned with a plurality of openings defined by the light-blocking structures, the elements, and the buffer layer.

Another embodiment of the present disclosure pertains to a semiconductor image sensor device. The image sensor device includes a substrate having a front side and a back side that is opposite the front side. An interconnect structure is disposed over the first side of the substrate. A plurality of pixels is located in the substrate. The pixels are each configured to detect light that enters the substrate from the back side. A dielectric layer is disposed over the back side of the substrate. A plurality of light-reflective structures is disposed over the back side of the substrate. A plurality of segments is each disposed between the dielectric layer and a respective one of the light-reflective structures. The segments each contain a metal material or a dielectric material different from the dielectric layer. A plurality of color filters is disposed between the light-reflective structures. Each of the color filters is aligned with a respective one of the pixels.

Yet another embodiment of the present disclosure pertains to a method of fabricating a semiconductor image sensor device. A substrate is provided. The substrate comprises a pixel region, a periphery region, and a bonding pad region. The pixel region contains a plurality of radiation-sensing regions. The first side of the substrate is bonded to a carrier substrate. Thereafter, the substrate is thinned from a second side opposite the first side. A buffer layer is formed over the second side of the substrate after the thinning. A first layer is formed over the buffer layer. The first layer and the buffer layer have different material compositions. A plurality of light-reflective structures is formed over the first layer. The light-reflective structures and the first layer define a plurality of openings that are each aligned with a respective one of the pixels. A second layer is formed over the light-reflective structures. The second layer fills the openings. The second layer and the first layer have different material compositions. Portions of the substrate in the bonding pad region are removed. Thereafter a bonding pad is formed in the bonding pad region. Thereafter, the second layer is removed with a first etching process. The first layer serves as a first etching-stop layer in the first etching process. Thereafter, portions of the first layer disposed below the openings are removed with a second etching process. The buffer layer serves as a second etching-stop layer in the second etching process.

Another one embodiment of the present disclosure pertains to a semiconductor image sensor device. The image sensor device includes a substrate having a first side and a second side that is opposite the first side. An interconnect structure is disposed over the first side of the substrate. A plurality of radiation-sensing regions are located in the substrate. The radiation-sensing regions are configured to sense radiation that enters the substrate from the second side. A plurality of light-blocking structures is disposed over the second side of the substrate. A passivation layer is coated on top surfaces and sidewalls of each of the light-blocking structures. A plurality of spacers is disposed on portions of the passivation layer coated on the sidewalls of the light-blocking structures.

Another embodiment of the present disclosure pertains to a semiconductor image sensor device. The image sensor device includes a substrate having a front side and a back side that is opposite the front side. An interconnect structure is disposed over the first side of the substrate. A plurality of pixels is located in the substrate. The pixels are each configured to detect light that enters the substrate from the back side. A plurality of light-reflective structures is disposed over the back side of the substrate. A passivation layer is coated on top surfaces and sidewalls of each of the light-reflective structures. A plurality of spacers is disposed on portions of the passivation layer coated on the sidewalls of the light-reflective structures but not over the top surfaces of the light-reflective structures. The spacers and the passivation layer have material compositions that are configured such that the spacers and the passivation layer have substantially different etching rates. A plurality of color filters is disposed between the light-reflective structures. The color filters are each aligned with a respective one of the pixels. The color filters are isolated from the light-reflective structures by the passivation layer and the spacers.

Yet another embodiment of the present disclosure pertains to a method of fabricating a semiconductor image sensor device. A substrate is provided. The substrate comprises a pixel region, a periphery region, and a bonding pad region. The pixel region contains a plurality of radiation-sensing regions. The first side of the substrate is bonded to a carrier substrate. Thereafter, the substrate is thinned from a second side opposite the first side. A plurality of light-reflective structures is formed over the second side of the substrate after the thinning. The light-reflective structures partially define a plurality of openings that are each aligned with a